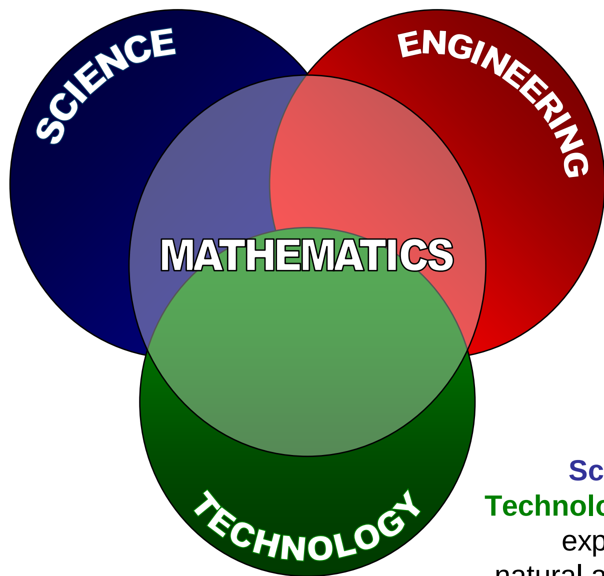
User's Guide to the Tennessee Science Curriculum Framework

Tennessee Vision for STEM Education

Engineering creatively applies scientific principles to analyze events, design processes, develop materials, and construct objects that benefit society.

Science seeks to explain the complexity of the natural world and uses this understanding to make valid and useful predictions.



Technology utilizes innovative tools, materials, and processes to solve problems or satisfy the needs of individuals, society, and the environment.

Science, **Engineering** and **Technology** use **Mathematics** to explore questions about the natural and human-made worlds.

Adapted with permission from the Massachusetts Science and Technology / Engineering Curriculum Frameworks.

Revised Standards Approval Dates: K-8 Nov. 2, 2007, 9-12 Jan. 25, 2008
Implementation: School Year 2009-2010

NOTE: This document is a "work in progress" and will undergo subsequent revisions as needed.

Introduction

Welcome to the User's Guide for using the 2007 version of the *Tennessee Science Curriculum Framework*. Approximately every six years the Department of Education is mandated by the Tennessee State Board of Education's *Rules, Regulations, and Minimum Standards* to revisit all of the state's curriculum standards. The 2007 revised science standards resulted from the efforts of committees comprised of science educators from across the state that worked diligently to develop standards that address all learners and are:

- Focused on major science themes
- Better organized
- Stated more clearly and concisely
- Increasingly complex across K-12
- Aligned with the National Science Education Standards, Benchmarks for Science Literacy, National Association for Educational Progress standards, and ACT Standards
- Easier to implement than previous versions

Overview of the 2007 Science Curriculum Framework Revision Process

Teams of K-12 teachers and college science educators from across Tennessee pooled their collective talent, wisdom, and experience to prepare the 2007 *Science Curriculum Framework*. Committee deliberations were thoughtfully enhanced by feedback from teachers about science teaching and learning, material found in exemplary state science content standards, and information gleaned from reports that reviewed earlier versions of the Tennessee Standards. Highlights of the revision process are described below.

Feedback gathered from teachers since release of the 2001 version of the Tennessee Standards indicated that the previous Framework could be improved by:

- Creating standards categories that are clear and concise as to their purpose and intent.
- Replacing the grade cluster configuration with a series of individual grade level expectations that offer better guidance for organizing a coherent K-8 curriculum sequence.
- Combining major standards topic areas where there was overlap.
- Placing all Learning Expectations in the most appropriate standards topic areas.
- Providing guidelines for incorporating inquiry into the curriculum.
- Scaffolding expectations for students into carefully articulated K-high school learning progressions.
- Refocusing on Expectations as the goals for student learning instead of State Performance Indicators that are used by the state to develop standardized tests.

The Mid-Central Regional Education Lab (McREL) study commissioned by the TN Department of Education (DOE) in 2006 raised the following concerns about the 2001 science standards:

- Accomplishments tended to be broad in scope and not all major topics addressed

- Many accomplishments duplicated at two or more grade levels
- Significant clarity issues resulted from the embedding of the process of inquiry into content standards
- Multiple organizing layers within the standards presented issues in terms of the relationships among components
- Blueprint for Learning uses terminology inconsistent with the standards that may create confusion Webb's Analysis of rigor and relevance conducted in 2006 revealed that the 2001 *Framework*:
- Alignment of standards and associated assessment items generally very good
- Science performance indicators primarily expect students to have basic skills in science, with very little expectations for conducting scientific reasoning
- Many standards and corresponding assessment items found to be at lower levels of Webb's Depth of Knowledge

The Fordham Report, which rated the 2001 TN Science Standards highly, offered the following observations:

- Organization is complicated by subdivision of individual Benchmarks into "levels"
- Covers physical sciences very well, small errors of fact or exposition
- Life sciences gets good handling, especially in high school
- Remarkable and encouraging is the reversal of Tennessee's approach to evolutionary science ...evolutionary science is covered and properly sequenced
- Grade "B"

Data and recommendations from all of the above sources were incorporated into the 2007 *Curriculum Framework*. The new standards continue to be aligned with the *National Science Education Standards* and *Benchmarks for Science Literacy*. ACT Benchmarks and the National Association for Educational Progress (NAEP) provided additional avenues for alignment. The resulting 2007 *Curriculum Framework* includes substantive changes in both the content and organization of the standards that are aimed at improving the quality of K-12 science education available to all Tennessee students.

The new *Tennessee Science Curriculum Framework* supports research-based approaches to science teaching and is consistent with what is known about how students learn science. Teachers and administrators can use the *Framework* to plan and implement a comprehensive K-12 science program that is aligned with state and national science education goals and prepares students for success with the Tennessee Comprehensive Assessment Program (TCAP). The K-8 *Science Standards* provide the necessary foundation for students to successfully meet rigorous course specific standards contained in the high school science sequence.

While the new science standards are not prescriptive in defining any particular instructional sequence, they provide helpful guidelines for local education agencies to implement the curriculum and instructional changes implicit in the new K-12 science standards. The following sections of the User's Guide describe major changes in the *Framework*, offer a rationale for the revised format, introduce Tennessee's vision for science education, and describe the standards revision process.

High School Science Redesign

Changes

1. Effective with the ninth grade class entering high school during school year 2009-2010, all students will pursue a focused program of study that includes three credits in science. One credit must be in Biology or Biology for Technology; one credit in Chemistry or Physics; and one additional laboratory science credit.
2. *Conceptual Physics* is a new course offering that is typically offered in ninth grade. It would meet the Physics graduation requirement.

Rationale for High School Science Redesign

Numerous publications point out that unlike their counterparts in other countries, American children display little or no mastery of physics concepts. National tests including PISA and NAEP, international assessments (TIMSS), and reports, such as the Glenn Commission, urge that the United States carefully redesign high school science and mathematics programs. Reform efforts are necessary to ensure that our educational system prepares adequate numbers of scientists, engineers, and mathematicians to sustain the growth of our economy.

Conceptual Physics is an outgrowth of the Physics First movement established by Nobel laureate, Leon Lederman and is the critical component of true High School Science Redesign. Physics First advocates recommend that students' initial exposure to the foundation ideas of Physics be from a conceptual rather than a mathematical perspective.

The paucity of significant change in secondary schools since the 1800's is dramatically borne out by Lederman. He states,

> "A time traveler from the year 1899 would be continually amazed by our advanced technology – our cars and airplanes, our skyscraper cities, our TV, radio, computers, and communication abilities. Probably the traveler would be most shaken by our science, from astronomy to zoology. The only place in which this visitor would be comfortably at home is in most of our high schools." http://members.aol.com/physicsfirst/

Lederman's observation is especially relevant in discussions about offering Physics as the introductory course in the high school science sequence.

Implications for Science Teaching and Learning

When a school district decides to adopt Physics as the first course in its high school science sequence, it causes a ripple effect throughout the entire high school science program. Taking physics in grade nine provides a student with a better basis for understanding concepts introduced later in Chemistry and Biology.

BSCS director, Rodger Bybee states,

> “Although connections among the sciences are critical for scientific literacy, traditional courses (sequence) treat the scientific disciplines as independent and unrelated. Lederman identifies the hierarchical relationships among concepts and principles leading from physics to chemistry and biology and illustrates with this example:
>
> A key biology content standard is “matter, energy and organization in living systems.” All energy used by living systems ultimately comes from the sun through electromagnetism (light). Energy transformations can be explained by using concepts from chemistry. Through energy transformations, plants make food (energy) which flows through the ecosystem. The availability of energy largely determines the distribution of populations (organisms) in the ecosystem. Atomic and molecular reactions with photons (light) and with one another are the underlying phenomena. (Lederman, 1998, p.18)

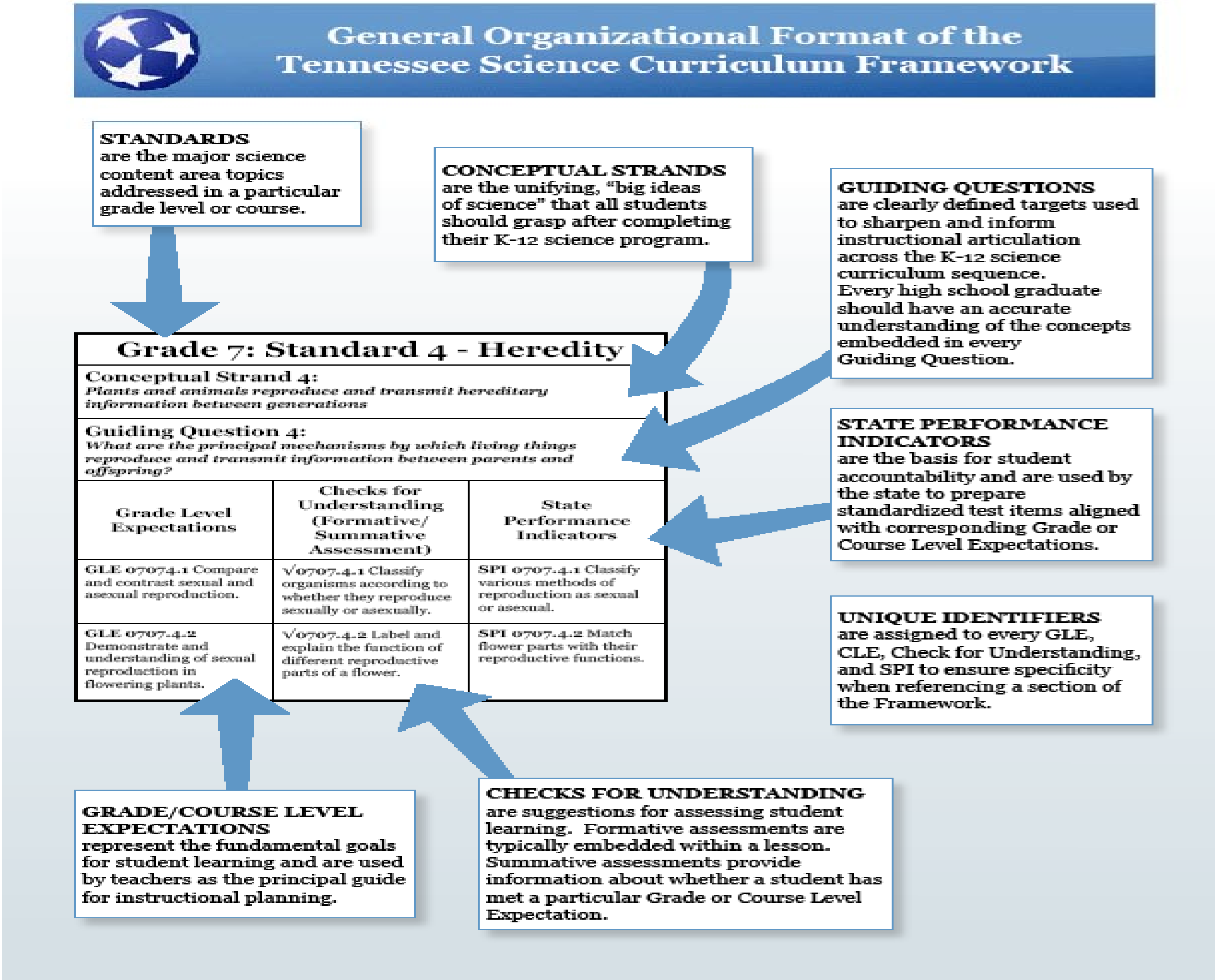
Implementing a ninth grade conceptual physics course naturally generates the need for examining both the content and pedagogy of the courses that follow. This is the type of systemic change associated with meaningful High School Science Redesign. The two components of the science redesign movement in Tennessee are the catalysts for change that will move schools toward better preparing students for post-secondary education and/or work in the technical workplace of the twenty first century.

Major Features of the 2007 Science Curriculum Framework

To guarantee successful implementation of the *2007 Science Curriculum Framework* it is important that all stakeholders be given a full explanation of the changes in the new document, the rationale for such modifications, and a description of the educational implications of these revisions. Science Standard 4 (Heredity) for Grade 7 (figure 1) will be used throughout this section to illustrate the key features of the *new Framework*.

Figure 1: Science Standard 4: Heredity

(Note: To simplify this review, not all GLEs, Checks for Understanding and SPIs have been included in this figure)



Conceptual Strands and Guiding Questions

Change

These are **new** features of the revised *Framework*. Every content standard area in each grade level or course includes a Conceptual Strand and Guiding Question. These statements are consistently applied across all K-8 grade levels and in high school courses such as Physical Science and Biology.

Rationale

Conceptual Strands are statements that express the unifying, "big ideas of science." The implicit goal of the Science Curriculum Framework is for all students to gain a thorough grasp of these fundamental concepts after completing their K-12 science program.

Guiding Questions are the focusing elements of the *Science Curriculum Framework*. Their major purpose is to give teachers and administrators clearly defined targets that they can use to sharpen and inform instructional articulation across the K-12 science curriculum sequence. It is expected that every high school graduates' cumulative science experiences will prepare them to thoughtfully demonstrate an accurate understanding of the concepts embedded in every Guiding Question when they exit from any Tennessee K-12 science program.

Implications for Science Teaching and Learning

Although Conceptual Strands cut across all grade levels, their implementation will naturally vary according to students' age, developmental readiness, and complexity of the ideas embedded within a standard. For example, the Conceptual Strand for Standard 4 – Heredity: "*Plants and animals reproduce and transmit hereditary information between generations*," has significantly different learning implications for students in grade seven as compared with those enrolled in a high school Biology course.

To illustrate how a Guiding Question might be applied to inform instruction, return to Standard 4 – Heredity. The Guiding Question for this standard, "*What are the principal mechanisms by which living things reproduce and transmit information between parents and offspring?*" This Guiding Question would be consistently referenced as teams of teachers map an appropriate K-12 learning progression and plan their corresponding instructional programs.

Grade Level and Course Expectations

Changes

In the 2001 document, "Learning Expectations" for every standard were provided for each K-8 grade cluster (K-3, 4-5, 6-8) and all high school courses. "Accomplishments" were added to offer additional guidance in developing curriculum that was appropriate for specific grade levels. Both the Learning Expectations and Accomplishments categories have been eliminated from the *2007 Framework* and combined into Grade Level Expectations (GLE) for Grades K-8 and Course Level Expectations (CLE) for high school courses. The K-8 GLEs are foundational in nature and prepare students to meet the CLEs established for mandatory high school courses. Although they encompass topics from all three science areas, grades 6-8 include a specific content focus: grade 6/Earth and Space Science; grade 7/Life Science; grade 8/Physical Science.

Rationale

GLEs and CLEs, as the expressions imply, are clearly defined statements of what all students should know and be able to do upon completion of a particular grade level or course. As such, they provide the major curriculum focus under each standard heading. Careful attempts were made to avoid duplication of GLEs across grade levels, to place GLEs under the appropriate standard topic, and to organize the GLEs into logical and developmentally appropriate learning progressions.

Implications for Science Teaching and Learning

Districts will find GLEs and CLEs to be valuable targets for achieving vertical, i.e., grade level to grade level, or grade level to high school course curriculum alignment. Since GLEs and CLEs represent the fundamental goals for student learning, teachers should use them as their principal guide for instructional planning. When consistently applied, this practice provides students with a carefully scaffolded set of learning experiences that offer maximum opportunity for them to attain the desired content goals in each standard area and to succeed on state assessments.

In the example we have been following for Standard 4, Grade 7 (figure 1), the first Grade Level Expectation in the set of four is: GLE 0707.4.1 "*Compare and contrast sexual and asexual reproduction*." Teachers would target this GLE through a set of carefully crafted learning activities (e.g., lab activities, direct instruction, demonstrations, visuals, etc.) that would enable students to meet this learning goal. Then, they would apply one or more of the Checks for Understanding described below to accurately determine if students could distinguish between sexual and asexual reproduction.

✓Checks for Understanding (Formative and Summative)

Change

✓Checks for Understanding are **new** to the 2007 version of the *TN Science Curriculum Framework*. Every content standard for each grade level or course includes several Checks for Understanding.

Rationale

Checks for Understanding provide "suggestions" for assessing student learning. Formative assessments are typically embedded within a lesson or smaller unit of instruction. Often, they are used to determine if a specific skill or bit of knowledge has been mastered or acquired by the student. Such assessments provide immediate feedback that teachers can use to monitor ongoing student performance and inform instruction. Summative assessments provide information about whether a student has met a particular Grade or Course Level Expectation. The concept maps found in Figure 2 illustrate the distinction between Formative and Summative Assessments.

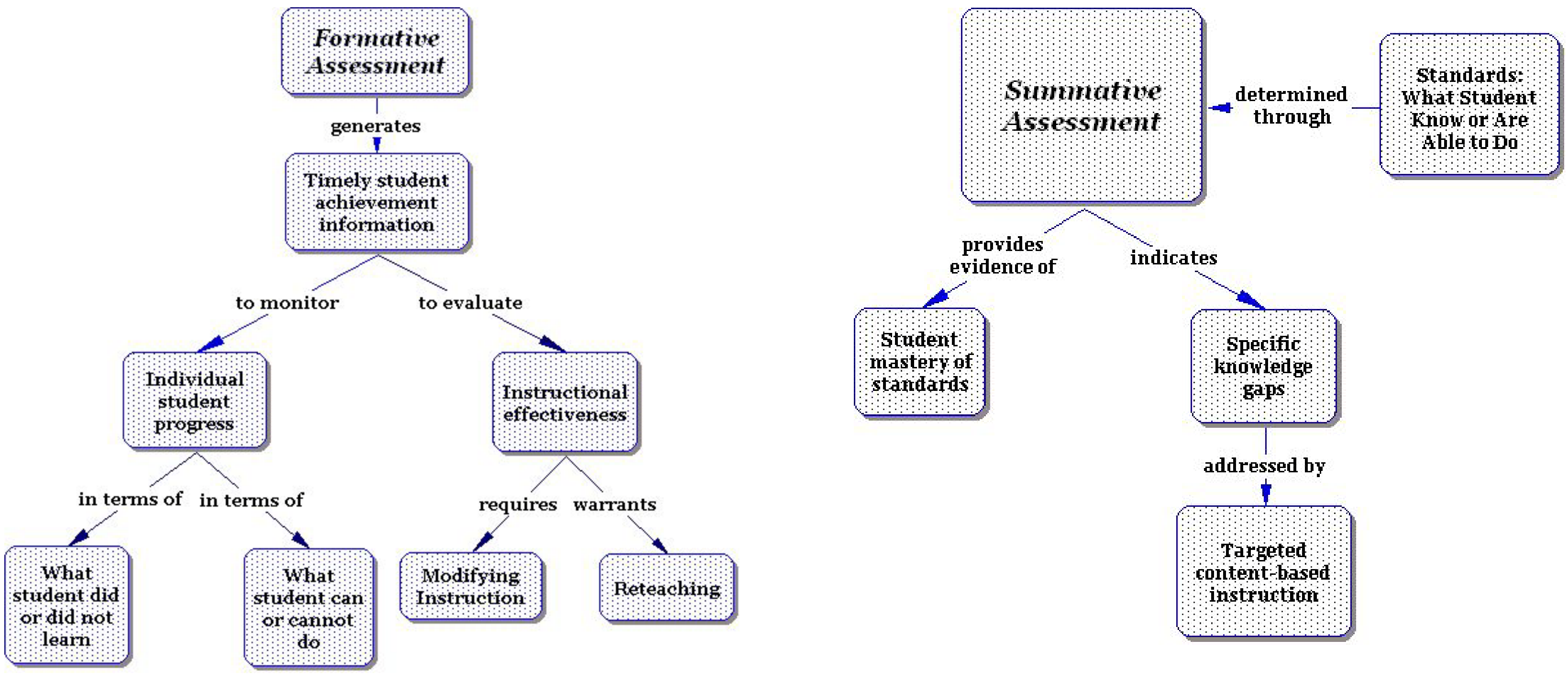
Implications for Science Teaching and Learning

Fewer aspects of education have changed more during the past 15-20 years than assessment. There is abundant research that demonstrates the importance and effectiveness of assessment as an aid to student learning. Teachers who consistently and frequently "check for student understanding" by integrating formative assessments into their

lessons obtain incremental, up-to-date feedback about the impact of their instruction on student learning. This enables them to capitalize on their successes or make necessary changes in their instruction to enhance their student's performance. Summative assessments are necessary to make determinations as to whether a certain GLE or CLE has been met. Both Formative and Summative assessments are integral components of the teaching and learning process.

In the *Tennessee Science Curriculum Framework* there is not a one-to-one correspondence between GLEs/CLEs and the Checks for Understanding. In the example we have been following for Standard 4, Grade 7 (figure 1), the second ✓Check for Understanding is: ✓0707.4.2 "*Label and explain the function of different reproductive parts of a flower*." As a formative assessment, students could be asked to create a Venn Diagram that compares and contrasts male and female plant reproductive structures. Additional Formative Assessments could be administered in subsequent lessons to determine if the foundation ideas needed to grasp the larger concept of plant reproduction were well understood.

Figure 2. Formative and Summative Assessment



For a summative assessment that corresponds to the Grade Level Expectation (GLE 0707.4.2) for this Check for Understanding, a teacher might require students to construct a fully labeled model that also describes the functions of the reproductive parts of a flower. Alternately, a summative assessment, such as a lab practical, could be designed to simultaneously assess several *related* GLEs.

State Performance Indicators

Changes

The State Performance Indicator category was retained in the 2007 version of the *TN Science Curriculum Framework*. While the category was maintained, many of the individual Indicators were reworded for the sake of clarity or to increase the level of rigor implied in the statement. Also, some indicators were eliminated and others added.

Rationale

State Performance Indicators provide the basis for student accountability. SPIs have and will continue to be used by the state to prepare standardized test items that are aligned with corresponding Grade or Course Level Expectations.

Implications for Science Teaching and Learning

Since State Performance Indicators are the criteria for developing aligned state assessments, they should have little direct impact on instruction. Testing companies use SPIs to develop test items that provide tangible evidence that the knowledge and skills described in the corresponding GLEs or CLEs for a particular Standard have been met by students.

Although the wording may differ slightly, there is a close correspondence between GLEs/CLEs and the SPIs in the *Tennessee Science Curriculum Framework*. In the example we have been following for Standard 4, Grade 7 (figure1), GLE 0707.4.2 "*Demonstrate an understanding of sexual reproduction in flowering plants*" and SPI 0707.4.1 "*Classify various methods of reproduction as sexual or asexual*" are very similar. Teachers who focus their instruction on this GLE should, in essence, be preparing their students for success on the state assessment that includes items aligned with the corresponding SPI. Suggestions for possible classroom assessments that measure student performance on this GLE are found under the Checks for Understanding.

Unique Identifiers

Changes

Every GLE, CLE, Check for Understanding, and SPI is assigned its own unique identification number.

Rationale

This numbering system ensures that all persons who use or reference the *Science Curriculum Framework* will be absolutely clear as to the specific part of the document under consideration.

Implications for Science Teaching and Learning

A system that provides every GLE, CLE, Check for Understanding, and SPI with its own unique identification number creates a level of specificity that teachers can apply when they map curriculum, select instructional materials, design assessments, or interpret state assessment data. As mentioned above, this system also supports clear lines of communication among all persons involved in providing standards-based instruction aligned with the *TN Science Framework*.

In the example we have been following for Standard 4, Grade 7 (figure1), the four digit number currently used by the state for reporting purposes for grade seven science (0707) is used in the GLE, Checks for Understanding, and SPIs.

Standards Titles, Numbers, Topic Area Emphasis

Changes

<u>The major changes in the organization of the 2007 *Science Framework* are as follows</u>:

- More clear and concise descriptors to identify standards, e.g., Content Standard: 7.0 Earth and Its Place in the Universe was changed to a simpler form, The Universe.
- Life Science Standards K-8 and Biology: standards reduced from six to five. Because of their topic similarity, Diversity and Adaptation among Living Things was combined with Biological Change to create the standard category, Biodiversity and Change.
- Earth and Space Science Standards: standards reduced from four to three. Because of their topic similarity, Earth Features was combined with Earth Resources to create the standard category titled, The Earth.
- Physical Science Standards: standards reduced from five to four. Because of their topic similarity, Structure and Properties of Matter was combined with Interactions of Matter to create the standard category called, Matter.
- Consistent numbers of GLEs were maintained across most K-8 grade levels <u>and</u> within the three major content areas. See the summary charts (figure 3 and Appendix A) for actual numbers.
- In grades 6-8, the three major content areas continue to be represented, but the content focus was shifted. Earth and Space Science is now the dominant area in grade 6; Life Science in grade 7; and Physical Science in grade 8.
- Life Science as a course for high school credit was eliminated.
- Conceptual Physics was added as a high school course option (see below).
- Embedded Standards were added for Inquiry, Technology and Engineering, and in some cases, Mathematics (see below).

Rationale

Because of the curriculum implications, no one grade level should contain a disproportionately high or low number of Grade Level Expectations for which students are being held accountable (figure 3). Shifting the emphasis to Physical Science concepts in grade 8 should support students who will soon after take physical science courses in high school.

Life Science was originally intended to serve as an intervention/remedial course for Gateway Biology. All high school students will be required to take the more rigorous Biology course.

Figure 3. Grade Level Distribution of GLEs and SPIs

Tennessee Standards Analysis										
	Grade Level Totals									
	K	1	2	3	4	5	6	7	8	All
Grade Level Expectations	21	24	28	39	35	32	29	29	29	270
Checks For Understanding	32	37	38	52	51	48	34	49	37	378
Stat Performance Indicators	-	-	-	28	28	29	26	33	32	176

K-8 TOTALS BY SCIENCE CONTENT AREA					
	Inquiry	Technology	Life Science	Earth Science	Physical Science
GLEs	42	33	70	50	71
SPIs	18	18	48	37	61

Implications for Science Teaching and Learning

In grades K-6, curriculum reorganization will be the major impact caused by changes in the number of standards. For grades 6-8, districts and teachers will have to realign the curriculum to reflect the modified distribution of Standards and Grade Level Expectations.

Embedded Inquiry, Engineering and Technology, Mathematics

Changes

Standards, Grade and Course Level Expectations, Checks for Understanding, and SPIs for Inquiry, Engineering and Technology (and in some courses, Mathematics) are included in the *Science Framework*. The general rigor of the *Framework* elements has been raised.

Rationale

Science, Technology, Engineering, and Mathematics (STEM) education is based on the assumption that to fully understand and apply science concepts they must be integrated with skills and understandings drawn from all of the associated areas. Throughout TN, universities have made major investments in STEM Education initiatives that actively embrace this perspective on teaching and learning science. Changes found in the new *Science Curriculum Framework* reflect this broad conceptual approach to science education. Embedded Standards are organized according to grade clusters (k-2, 3-5, 6-8, and 9-12). The grade cluster approach offers numerous opportunities for students to engage in inquiry, technology and engineering, and mathematics experiences that are directly integrated into the science content.

Earlier versions of the *TN Science Framework* placed action verbs in Learning Expectations to imply or suggest that these concepts be experienced through inquiry. This approach caused confusion and failed to support the goal of integrating inquiry-based learning throughout the K-12 science curriculum. Also, the more contemporary movement toward embedding mathematics and technology and engineering directly into the science curriculum is now integral to the *Science Framework*.

In 2006, the TN Department of Education conducted an external review of the TN Science Standards that evaluated the standards through the lens of Webb's Depth of Knowledge scale**.** Similar to Bloom's Taxonomy, Webb's scale categorizes a learning expectation in terms of the requisite knowledge or skill needed for a student to successfully meet this goal. Webb's four Levels are: Recall, Skill/Concept, Strategic Thinking, and Extended Thinking. The principal criterion for assigning a CLE or GLE to a knowledge level is the verb used in the learning expectation statement and the level of student engagement required to achieve the desired outcome.

The rigor and relevance of earlier versions of the *TN Science Framework* was identified by these external reviewers as a target for improvement. The addition of Embedded Standards for Inquiry, Technology and Engineering is a direct response to the panel's recommendations and illustrates that expectations have been raised for all K-12 science students Appendices B and C compare Webb's Level of Knowledge data from the 2001 and 2007 *Science Curriculum Frameworks*.

Implications for Science Teaching and Learning

The three Embedded Conceptual Strands are as follows:

Inquiry:

- *Understandings about scientific inquiry and the ability to conduct inquiry are essential for living in the 21st century.*

Technology and Engineering:

- *Society benefits when engineers apply scientific discoveries to design materials and processes that develop into enabling technologies.*

Mathematics:

- *Science applies mathematics to investigate questions and communicate findings.*

The skills and concepts included in the new Inquiry, Technology and Engineering, and Mathematics Standards are not expected to be taught as separate, individual topics. Rather, the embedded standards should be fully integrated or incorporated throughout every content area in the Curriculum Framework. In other words, students should not be taught about Inquiry and Engineering and Technology as discreet bits of knowledge, but rather be given multiple opportunities in every grade level and course to integrate these skills and concepts seamlessly into relevant science content.

Learning Progressions

Change

The 2007 standards revision committee was the first to use Learning Progressions to guide the alignment of standards in the *Science Curriculum Framework*.

Rationale

Learning Progressions are clusters of interrelated ideas that become increasingly complex across grade levels. The practice of using learning progressions to guide the development of Grade and Course Level Expectations relies on two fundamental understandings about how students learn. Firstly, learning occurs over time and through multiple exposures to concepts presented within different educational contexts. For this reason, Grade Level Expectations for major topic areas in the K-8 *Science Curriculum Framework* continuum are organized into scaffolded sets of ideas that are all embedded within an associated Conceptual Strand statement. Progress toward understanding the big idea of science expressed in the Conceptual Strand is expected to grow in complexity during the course of a student's education as they experience different opportunities to explore this concept. Secondly, learning is about making connections. Mastery of precursor ideas and skills found in earlier grade levels is essential because it contributes to understanding the more complex ideas students encounter at higher grade levels or in college.

After the elementary, middle, and high school teams developed their GLEs or CLEs, another team of science educators examined the *Frameworks* from a horizontal perspective to search for redundancies, gaps, and to make certain that these statements offered a logical and developmentally appropriate conceptual flow.

Implications for Science Teaching and Learning

Learning Progressions offer a clear picture of where the students have been and where they are headed. They can be used by districts to map and align K-12 curriculum, guide textbook selections, and as jumping off points for professional conversations about methods and approaches to improve science education.

The GLEs that we have been following for Standard 4, Grade 7 (figure 1) are one part of a set of scaffolded GLEs that all contribute to developing a rich and deep understanding of the Conceptual Strand statement for Heredity: *Plants and animals reproduce and transmit hereditary information between generations.*

Tennessee's Vision of Standards-Based Science, Technology, Engineering and Mathematics Education

The *Tennessee Science Curriculum Framework* presents an educational pathway designed to prepare every student to function in a society in which scientific and technological literacy are necessary for full participation and enjoyment. The new standards are founded on the premise that leaning science content is most successful when experienced through an active process that integrates inquiry, technology and engineering, and mathematics, in what is commonly referred to as STEM Education (figure 4).

The goal of standards revision is to develop a curriculum framework that will guide and support school systems in building a rigorous and relevant K-12 science curriculum. The educational vision reflected in the *Framework* is that a carefully designed, coherent, and properly implemented set of K-12 science learning experiences will enable all students to:

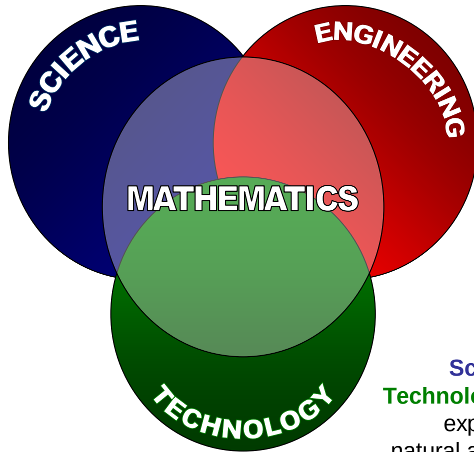
- Develop a deep understanding of the key scientific concepts, principles, theories, and laws drawn from the life, physical, earth and space sciences
- Apply scientific process skills by posing questions and investigating phenomena through the language, procedures, and tools of science
- Be aware of how engineering, technology, and mathematics are integrated into the historical and cultural advancement of the scientific enterprise
- Think and act in a way that demonstrates a positive attitude toward problem-solving and personal decision-making about issues that affect our society and the planet.

Figure 4. Tennessee Vision for STEM Education

Tennessee Vision for STEM Education

Engineering creatively applies scientific principles to analyze events, design processes, develop materials, and construct objects that benefit society.

Science seeks to explain the complexity of the natural world and uses this understanding to make valid and useful predictions.



Technology utilizes innovative tools, materials, and processes to solve problems or satisfy the needs of individuals, society, and the environment.

Science, **Engineering** and **Technology** use **Mathematics** to explore questions about the natural and human-made worlds.

Adapted with permission from the Massachusetts Science and Technology / Engineering Curriculum Frameworks.

Further, all Tennessee students should emerge from their K-12 science education experiences fully prepared for transitioning to higher education, careers in the technical workforce, and service to their communities or nation.

Implementation of Inquiry and Technology and Engineering

The Science Curriculum Framework is based on the premise that students learn science best by "doing" science. Embedded standards for inquiry and technology and engineering underline the importance of providing numerous, developmentally- appropriate interactive learning experiences for students in the course of their K-12 science education.

As a reminder, the Tennessee *Minimum Requirements for the Approval of Public Schools* (Rule 0520-1-3-.05 c) states the following:

> In Grades K-8. The science program shall be based on the state curriculum standards and shall be developmentally appropriate, with instruction *focusing on laboratory experiences*.

In Grades 9-12. Three units of science shall be required for graduation…*All science courses shall include laboratory science experiences.*

A recent National Research Council publication *America's Lab Report* defines "laboratory experiences" as those that provide opportunities to interact directly with the material world (or with data drawn from the material world), using the tools, data collection techniques, models, and theories of science. This definition is further elaborated with examples of student activities that include:

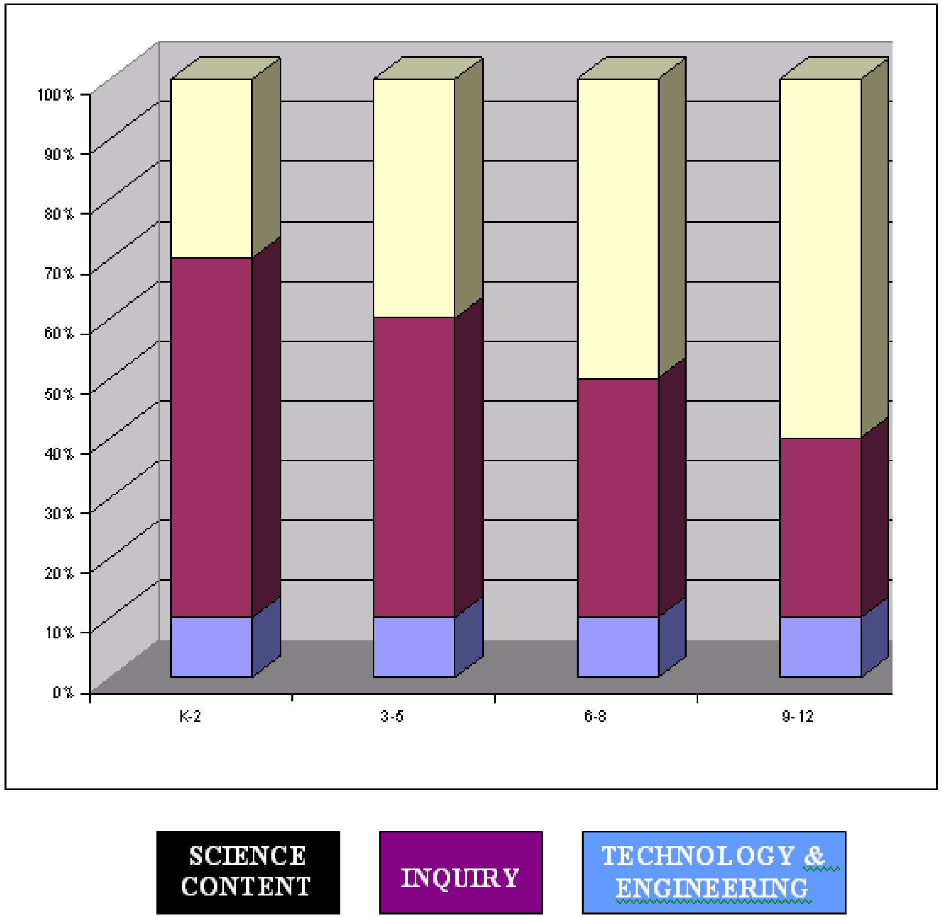
- physical manipulation of the real-world substances or systems under investigation
- interaction with simulations (models)
- interaction with data drawn from the real world
- access to large databases, and
- remote access to scientific instruments and observations.

The NRC report goes on to state that the extent to which laboratory experiences help students attain educational goals depends not only on how much time is spent in laboratory instruction, but even more importantly on the quality of that instruction. Effective lab experiences focus on the learning goals related to instruction, integrate student learning about the processes of science with learning about content, and incorporate thoughtful reflection and discussion between students and teachers.

The new standards and course and grade level expectations can and should be used by all stakeholders in the science education arena to guide whatever decisions are deemed necessary to support effective K-12 science programs. Because the Curriculum Framework is based on a developmental progression, teachers will introduce science content and skills at a level of sophistication consistent with a student's readiness to learn and discover. Similarly, different emphases will characterize instructional time allocations at individual grade levels.

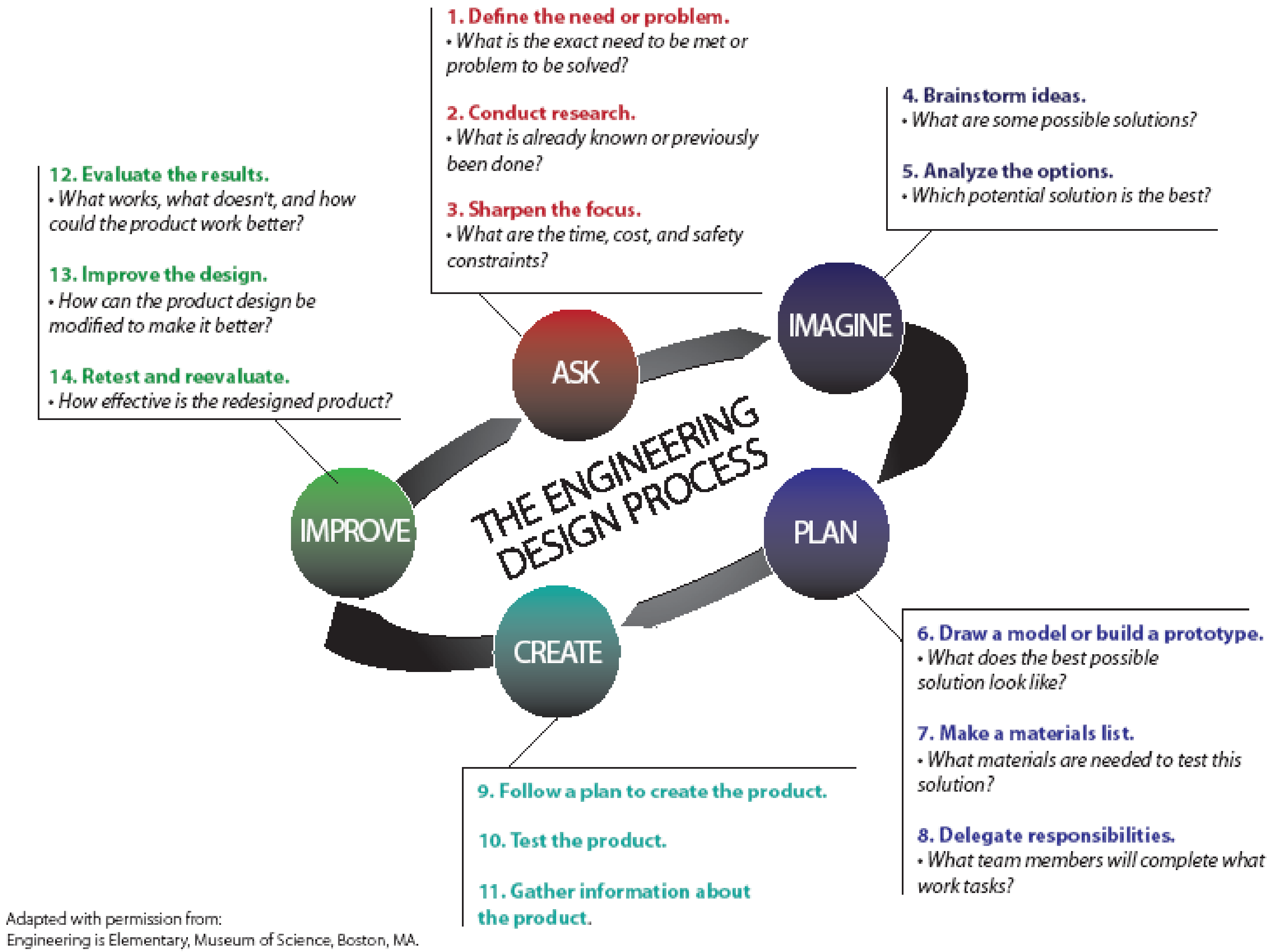
Figure 5 illustrates a *suggested* percentage of emphasis for the teaching of the content and integration of the embedded strands for inquiry and technology and engineering. The Standards' orientation toward the teaching science processes through inquiry in the lower grades and its shifting emphasis toward content knowledge in grades 9-12 and is consistent with the research on when students learn best.

Figure 5. Suggested Emphasis for Content, Inquiry, and Technology and Engineering



The Engineering Design Cycle pictured in figure 6 is **new** to the *Framework*. The inner section identifies the broad stages of the problem solving process. The outer part gives details about the procedures and questions that engineers use to address the problems that concern them. Teachers can use the design cycle model as a guide for developing learning activities that naturally integrate the Embedded Technology and Engineering Standards into their science curriculum.

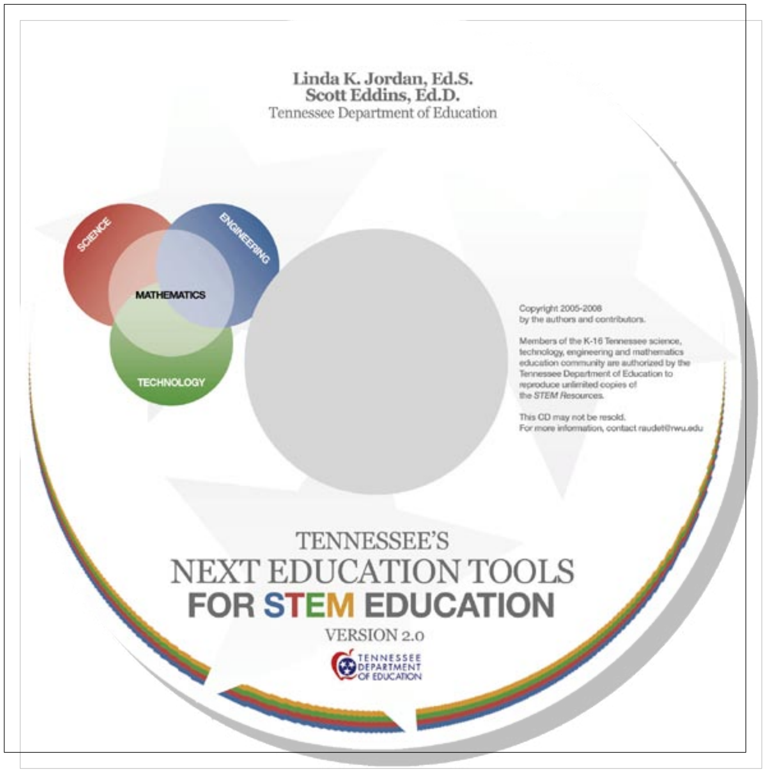
Figure 6. Engineering Design Cycle



Next Generation Tools for STEM Education

A Resource for Implementing the Tennessee Science and Mathematics Curriculum Frameworks

The materials found in the *Next Generation Tools for STEM Education* constitute a "toolkit" that can be used to support teachers who are moving toward standards-based practices. Within the contents, the term "standards-based" describes educational contexts wherein everything that is associated with teaching and learning is referenced to the national and state standards. The tools found on the disc can assist with the implementation of the science curriculum standards (SBE 2001). All of these standards-based tools have been customized to align with the Tennessee Science and Mathematics Curriculum Standards.



The *Next Generation Tools for STEM Education resource* was developed after recognizing that teachers need quality support materials and clear, high quality work samples for implementing the state curriculum standards. To be successful, every teacher must have appropriate instructional tools and the background preparation needed to implement curriculum standards in the classroom. Some materials, like grade and attendance managers, simplify routine classroom management

tasks. However, labor-saving technologies for delivering standards-based curriculum and instruction and for preparing aligned assessments are not routinely available to teachers. Without proper tools, effective implementation of many standards-based reform practices, while possible, are not really feasible for most teachers. The compilation of standards, curriculum development and instructional tools, science and mathematics teacher resources, and work samples found in the *Next Generation Tools for STEM Education* can facilitate the consistent delivery of high-quality, standards based instruction.

Appendix A. K-8 Standards Summary

Tennessee Revised Standards Analysis		
		GRADE LEVELS

	STANDARDS		K	1	2	3	4	5	6	7	8	Total
	Embedded Inquiry	Grade Level Expectations	3	3	3	6	6	6	5	5	5	42
		Checks For Understanding	4	4	4	4	4	4	5	5	5	39
		SPIs	-	-	-	1	1	1	5	5	5	18
	Embedded Technology and Engineering	Grade Level Expectations	2	2	2	5	5	5	4	4	4	33
		Checks For Understanding	3	3	3	4	4	4	5	5	5	36
		SPIs	-	-	-	2	2	2	4	4	4	18
LIFE SCIENCE	1 Cells	Grade Level Expectations	1	2	1	1	1	1	-	4	-	11
		Checks For Understanding	3	3	1	2	2	2	-	8	-	21
		SPIs	-	-	-	1	1	2	-	5	-	9
	2 Interdependence	Grade Level Expectations	2	1	3	2	1	3	4	-	-	16
		Checks For Understanding	2	3	3	3	2	5	4	-	-	22
		SPIs	-	-	-	2	1	3	4	-	-	10
	3 Matter & Energy	Grade Level Expectations	1	1	1	1	2	1	-	2	-	9
		Checks For Understanding	2	2	2	4	3	2	-	7	-	22
		SPIs	-	-	-	2	1	2	-	2	-	7
	4 Heredity	Grade Level Expectations	2	2	2	2	2	2	-	4	-	16

		Checks For Understanding	2	2	4	5	2	3	-	7	-	25
		SPIs	-	-	-	2	2	2	-	4	-	10
	5 Biodiversity & Change	Grade Level Expectations	1	2	2	2	2	2	-	-	7	18
		Check For Understanding	3	3	4	7	6	5	-	-	7	35
		SPIs	-	-	-	2	2	2	-	-	7	13
EARTH & SPACE SCIENCE	6 The Universe	Grade Level Expectations	1	2	2	1	1	2	7	-	-	16
		Checks For Understanding	2	2	2	2	2	3	7	-	-	20
		SPIs	-	-	-	1	2	3	7	-	-	13
	7 The Earth	Grade Level Expectations	2	2	3	4	2	1	-	6	-	20
		Checks For Understanding	3	3	4	5	4	2	-	9	-	30
		SPIs	-	-	-	4	2	1	-	7	-	14
	8 The Atmosphere	Grade Level Expectations	1	1	1	4	2	1	4	-	-	14
		Checks For Understanding	2	2	1	2	3	4	6	-	-	20
		SPIs	-	-	-	2	2	2	4	-	-	10
PHYSICAL SCIENCE	9 Matter	Grade Level Expectations	2	3	3	3	2	3	-	-	9	24
		Checks For Understanding	2	3	4	5	2	3	-	-	13	32
		SPIs	-	-	-	2	3	3	-	-	12	20

	10 Energy	**Grade Level Expectations**	2	1	1	2	3	2	3	-	-	14
		Checks For Understanding	3	3	2	2	4	5	4	-	-	23
		SPIs	-	-	-	2	4	2	4	-	-	12
	11 Motion	**Grade Level Expectations**	1	1	2	3	3	1	-	6	-	17
		Checks For Understanding	1	2	2	3	5	3	-	6	-	22
		SPIs	-	-	-	4	3	1	-	6	-	14
	12 Magnetic & Gravitational Forces	**Grade Level Expectations**	-	1	2	1	2	3	-	-	5	14
		Checks For Understanding	-	2	2	2	2	3	-	-	7	18
		SPIs	-	-	-	2	1	3	-	-	6	12

GRADE LEVELS	TOTAL # OF GRADE LEVEL EXPECTATIONS	DOK LEVELS	NUMBER OF GRADE LEVEL EXPECTATIONS BY DOK LEVEL (2007)	DOK LEVELS	% DOK W/IN GRADE BY LEVEL 2007	2001
K	21	1	11	1	52	
		2	9	2	43	
		3	-	3	-	
		4	1	4	5	
1	24	1	6	1	25	
		2	17	2	71	
		3	-	3	-	
		4	1	4	4	
2	28	1	5	1	18	
		2	20	2	71	
		3	2	3	7	
		4	1	4	4	
3	36	1	3	1	8.5	79
		2	26	2	72	21
		3	4	3	11	-
		4	3	4	8.5	-
4	33	1	4	1	12	75
		2	22	2	67	25
		3	6	3	18	-
		4	1	4	3	-
5	33	1	7	1	21	68
		2	16	2	49	31
		3	9	3	27	-
		4	1	4	3	-
6	27	1	-	1	-	60
		2	14	2	52	40
		3	10	3	37	-
		4	3	4	11	-
		1	-	1	-	73

7	31	2	23	2	74	23
		3	7	3	23	3
		4	1	4	3	-
8	28	1	2	1	7	60
		2	19	2	68	36
		3	5	3	18	2
		4	2	4	7	-

Appendix C. Webb's Depth of Knowledge Data: Physical Science and Biology

Physical Science and Biology Webb's Depth of Knowledge Levels								
COURSE	TOTAL # OF COURSE LEVEL EXPECTATIONS		DOK LEVELS	COURSE LEVEL EXPECTATIONS BY DOK LEVEL		DOK LEVELS	% DOK BY LEVEL	
	2002	2007		2002	2007		2002	2007
Biology 1	28	35	1	3	1	1	10	3
			2	22	23	2	80	66
			3	3	10	3	10	29
			4	---	1	4	---	3
Physical Science	18	34	1	3	2	1	17	6
			2	11	16	2	61	53
			3	4	11	3	22	37
			4	---	1	4	---	3